

**CLAIMS**

We Claim:

5 1. A weldable workpiece having at least its surface made from a first polymer which softens on heating adapted for fusing to a material which softens on heating and is freely-selectable from a second polymer which is the same or similar to the first polymer or a different polymer which is at least locally mutually miscible with the surface of the first polymer, wherein the first polymer and the freely-selectable second polymer have overlapping melting temperature ranges, the workpiece comprising:

10 (a) said workpiece having a bulk portion with said surface extending across said bulk portion;

15 (b) an absorber dye possessing both strong absorption and a high extinction coefficient at a welding wavelength of a radiant energy source;

20 said dye being deposited on or above said workpiece surface thereby defining a welding zone via a vehicle having necessary viscosity and which avoids undue interference with or occlusion of the welding zone, wherein said deposition comprising a generally uniform density of about 5 to about 3000 nanograms of dye per  $\text{mm}^2$  to provide predictable and consistent heating thereby rendering said workpiece weld-enabled; and

25 (c) said welding zone having the capacity to convert inbound radiant energy at said welding wavelength over about  $0.1 \text{ J/mm}^2$  into thermal energy via vibronic relaxation immediately followed by exothermic decomposition of at least a portion of said dye into inert, invisible by-products, the combination of which being capable of delivering (i) a first quantity of thermal energy directed in the direction of said bulk portion to elevate said surface into the melting

temperature range of said surface and (ii) an approximately equal quantity of thermal energy directed in the opposite direction away from said bulk portion;

5 wherein said dye, said vehicle, said by-products, and said surface of said first polymer are mutually miscible.

2. The workpiece of claim 1, wherein said workpiece is made from a first thermoplastic polymer.

10 3. The workpiece of claim 2, wherein the vehicle comprises a film.

4. The workpiece of claim 3, wherein the vehicle includes a thermoplastic material.

5. The workpiece of claim 1, wherein the vehicle comprises a film.

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6. The workpiece of claim 4, wherein said film includes a thermoplastic material.

7. The workpiece of claim 1, wherein said dye is selected from the group consisting of a visible light absorbing dye, a near infrared absorbing dye, an infrared absorbing dye, and combinations thereof.

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8. The workpiece of claim 1, wherein the vehicle includes a liquid solvent that dissolves the absorber dye.

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9. The workpiece of claim 8, wherein said vehicle delivers a portion of said absorber dye below said surface to a depth sufficiently small to avoid foaming during welding.

10. The workpiece of claim 9, wherein said absorber dye is present in a concentration of about 1 X 10<sup>-2</sup> to about 1 X 10<sup>-4</sup> grams per milliliter of liquid solvent to deliver the surface deposition density.

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11. The workpiece of claim 1, wherein said absorber dye possesses strong absorption and a high extinction coefficient at a welding wavelength selected from the group consisting of a visible spectrum welding wavelength, a N/R welding wavelength, an IR welding wavelength, and combinations thereof.

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12. A transmission-enhancing formulation disposed between a first reflective surface of a first radiant energy-transmissive workpiece having a first bulk portion and a second reflective surface of a second workpiece having a second bulk portion, wherein both reflective surfaces are made of a polymer material which softens on heating, wherein the transmission at a welding wavelength of a radiant energy source along an optical path through the formulation and the bulk portions and the reflective surfaces is lower than the optical transmission through just the bulk portions and the reflective surfaces only, wherein the first and second reflective surfaces are made of polymers having overlapping melting temperature ranges, wherein the transmission-enhancing formulation comprises:

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a material system containing a radiant energy absorbing dye having both strong absorption and a high extinction coefficient matched to the welding wavelength of the radiant energy source; and

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said material system being capable of directing said lower optical transmission attributable to the formulation into thermal energy via successive electronic-to-thermal and chemical-to-thermal conversion activities, wherein said thermal energy is transferable into the reflective surfaces disposed within the same optical path as said material system;

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wherein said thermal energy transfer being capable of welding the transmission-reducing reflective surfaces together into a transmission-enhancing region having the bulk portions optically fused together.

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13. The formulation of claim 12, wherein the transmission-enhanced region exhibiting an optical transmission within the visible spectrum greater than the transmission through both portions and both reflective surfaces only.

14. The formulation of claim 13, wherein the transmission-enhanced region exhibiting an optical transmission at selected wavelengths within the visible spectrum of about 10% more than the transmission through both portions and both reflective surfaces only.

5 15. The formulation of claim 13, wherein the transmission-enhanced region exhibiting an optical transmission at selected wavelengths within the visible spectrum of about 1.1 times greater than the transmission through both portions and both reflective surfaces only.

10 16. The formulation of claim 12, wherein the transmission-enhanced region exhibiting a photopic transmission greater than the photopic transmission through both portions and both reflective surfaces only.

15 17. The formulation of claim 12, wherein the transmission-enhanced region exhibiting a photopic transmission of about 10% more than the photopic transmission through both portions and both reflective surfaces only.

20 18. The formulation of claim 12, wherein the transmission-enhanced region exhibiting a photopic transmission of about 1.1 times greater than the photopic transmission through both portions and both reflective surfaces only.

19. The formulation of claim 12, wherein the material system is mutually miscible with said first and second reflective surfaces to avoid occluding the transmission-enhancing region.

25 20. The formulation of claim 12, wherein the optical transmission along the optical path through the formulation is about 10% lower than the optical transmission through the bulk portions and the reflective surfaces.

30 21. The formulation of claim 12, wherein the optical transmission along the optical path through the formulation is about 0.9 times lower than the optical transmission through the bulk portions and the reflective surfaces.

22. The workpiece of claim 12, wherein said dye is selected from the group consisting of a visible light absorbing dye, a near infrared absorbing dye, an infrared absorbing dye, and combinations thereof.

5 23. The workpiece of claim 12, wherein said absorber dye possesses strong absorption and a high extinction coefficient at a welding wavelength selected from the group consisting of a visible spectrum welding wavelength, an NIR welding wavelength, an IR welding wavelength, and combinations thereof.

10 24. The formulation of claim 12, wherein chemical-to-thermal conversion comprises exothermic decomposition of said dye into inert, invisible by-products, wherein said dye, said vehicle, said by-products and said reflective surfaces are mutually miscible.

15 25. The formulation of claim 24, wherein mutual miscibility comprises numerical proximity of the Hansen solubility parameters of said dye, said vehicle, said by-products and said reflective surfaces.

20 26. The formulation of claim 25, wherein said numerically proximate Hansen solubility factors provide minimal occlusion of the optical transmission within the transmission-enhancing region.

27. A method of preprocessing a workpiece made from a first polymer for the exclusive purpose of preparing it for a high-efficiency through transmission radiant energy welding operation fusing the workpiece to a mating panel made from a material which softens on heating and is freely selectable from a second polymer which is the same or similar to the first polymer or a different polymer which is at least locally miscible with the surface of the first polymer, wherein the first polymer and the freely-selectable second polymer have overlapping melting temperature ranges, comprising the steps of:

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30 forming a radiant energy director in the form of a substantially laminar welding zone comprising the steps of (i) selecting a first polymer which softens on heating and includes a bulk portion and a surface extending across the bulk portion, (ii) selecting a dye possessing both

strong absorption and a high extinction coefficient at a welding wavelength of a radiant energy source, (iii) selecting a dye vehicle with sufficient viscosity to define the edge of the welding zone and avoid undue interference with the welding operation or occlusion of the ultimately fused portion, and (iv) depositing, via the dye vehicle, between 5 and 3000 nanograms of dye per 5 mm<sup>2</sup> on or above the workpiece surface,

wherein said radiant energy director having the capacity to undergo electronic, chemical and mechanical transformations during the welding operation according to the following steps of (1) converting inbound radiant energy at said welding wavelength over about 0.1 Joule/mm<sup>2</sup> into thermal energy via vibronic relaxation, (2) exothermically decomposing at least a portion of said dye into inert, invisible by-products immediately following said converting step, and (3) during said converting and decomposing steps, delivering a first quantity of energy into the bulk portion to elevate the surface into the melting temperature range of the first polymer and delivering an approximately equal second quantity of energy in the opposite direction away from the bulk portion.

28. The method of claim 27, wherein said workpiece is made from a first thermoplastic polymer.

29. The method of claim 28, wherein the vehicle comprises a film.

30. The method of claim 29, wherein the vehicle includes a thermoplastic material.

31. The method of claim 27, wherein the vehicle comprises a film.

25 32. The method of claim 31, wherein said film includes a thermoplastic material.

33. The method of claim 27, wherein said dye is selected from the group consisting of a visible light absorbing dye, a near infrared absorbing dye, an infrared absorbing dye, and combinations thereof.

34. The workpiece of claim 27, wherein said absorber dye possesses strong absorption and a high extinction coefficient at a welding wavelength selected from the group consisting of a visible spectrum welding wavelength, a NIR welding wavelength, an IR welding wavelength, and combinations thereof.

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35. The method of claim 27, wherein the vehicle includes a liquid solvent that dissolves the absorber dye.

10 36. The method of claim 35, wherein said vehicle delivers a portion of said absorber dye below

said surface to a depth sufficiently small to avoid foaming upon welding.

37. The method of claim 36, wherein said absorber dye is present in a concentration of about  $1 \times 10^{-2}$  to about  $1 \times 10^{-4}$  grams per milliliter of liquid solvent to deliver the surface deposition density.

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38. The method of claim 27, wherein chemical-to-thermal conversion comprises exothermic decomposition of said dye into inert, invisible by-products, and wherein said dye, said vehicle, said by-products and said reflective surfaces are mutually miscible.

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39. The method of claim 38, wherein mutual miscibility comprises numerical proximity of the Hansen solubility parameters of said dye, said vehicle, said by-products and said reflective surfaces.

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40. The method of claim 39, wherein said numerically proximate Hansen solubility factors provide minimal occlusion of the optical transmission within the transmission-enhancing region.